REVIEW ARTICLE

Can complex contrast training interventions improve aerobic endurance, maximal strength, and repeated sprint ability in soccer players? A systematic review and meta-analysis

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Abstract

This systematic review and meta-analysis aimed to assess the effects of complex contrast training (CT) on aerobic endurance, maximal strength, and repeated sprint ability (RSA) in soccer players. After an electronic search, nine peer-reviewed articles were considered, including soccer players from junior to professional-level (age 14 – 23 years). One study was conducted during the pre-season, seven studies during the in-season, and one study during the off-season period of a competitive schedule. The studies included were of moderate to high methodological quality (PEDro scale) and incorporated CT with soccer practice. Large significant improvements (ES = 1.30; 95% CI = 0.61 – 2.00; $p < 0.001$; $I^2 = 80.6\%$) for maximal strength, and small non-significant improvements for aerobic endurance (ES = 0.33; 95% CI = -0.19 – 0.85; $p = 0.209$; $I^2 = 0.0\%$) and RSA (ES = 0.32; 95% CI = -0.12 – 0.75; $p = 0.156$; $I^2 = 0.0\%$) were noted for CT groups when compared to active or specific-active control groups. Therefore, supplementing regular soccer training with CT induces adaptations to improve maximal strength. CT may be implemented during the pre-season and in-season to induce adaptations similar to traditional strength training (e.g., maximal strength gains), although alternative training strategies may be needed to further improve aerobic endurance and RSA. The use of CT may be applicable during different periods of the season to achieve certain goals, e.g., pre- and in-season for maximal strength development, and off-season to attenuate the decline of strength or power.

Keywords: *football, plyometric exercise, human physical conditioning, resistance training, muscle strength, movement*

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Introduction

Soccer requires a combination of aerobic and high-intensity demands (e.g., sprints, changes of direction) (Barnes et al., 2014; Bush et al., 2015), which defines the match running performance among professional soccer players (Modric et al., 2022; Modric, Versic, et al., 2021). Indeed, these demands during training sessions may also determine the outcomes of matches (Modric, Jelicic, et al., 2021). A common method to assess these demands in soccer players is the Yo-Yo intermittent recovery test (Yo-Yo IRT) (Castagna et al., 2020; Deprez et al., 2015). Indeed, elite players show better Yo-Yo IRT performance compared to sub-elite (2,420 m versus 2,030 m) (Bangsbo et al., 2008). In addition to aerobic endurance, short-duration maximal- and near-maximal physical efforts (e.g., vertical jumps) are prevalent in soccer, and are required to overcome opponents during play (Stølen et al., 2005). These maximal- or near-maximal efforts have shown to be positively associated with the strength of lower limbs (e.g., maximal squat strength) (Arnason et al., 2004; Requena et al., 2009; Thapa et al., 2019; Wisløff et al., 2004). Moreover, maximal strength of lower limbs (e.g., one repetition maximum [1RM]) may also be used to differentiate the player's playing level (e.g., professional versus amateur) (Cometti et al., 2001). Another relevant aptitude in soccer players is the ability to repeatedly produce maximal sprints with brief recovery periods (Rampinini et al., 2007), considering the ever-increasing high-intensity running demands (e.g., ~30 % increase in high-intensity running distance between 2006 versus 2012) (Barnes et al., 2014; Bush et al., 2015; Dellal et al., 2011). Based on the available evidence aerobic endurance (Bangsbo et al., 2008), muscle strength (Gissis et al., 2006; Reilly et al., 2000), and repeated sprint ability (RSA) (Chaouachi et al., 2010; Stølen et al., 2005) are important physical characteristics for soccer players.

Traditional strength training with exercises such as heavy squat (McKinlay et al., 2018; Silva et al., 2015) and plyometric jump training with exercises implicating a fast stretch-shortening cycle muscle action (Ramirez-Campillo, Gentil, et al., 2021; Sánchez et al., 2020; van de Hoef et al., 2019) may improve aerobic endurance, strength, and RSA. However, compared to a single training mode, a combination of resistance and plyometric/ballistic exercise (i.e., complex contrast training [CT]) may further improve aerobic endurance, strength, and RSA in soccer players (Faude et al., 2013; Hammami et al., 2017a). CT involves the performance of a high-load low-speed resistance training exercise, followed immediately by the execution of a low-load high-speed plyometric/ballistic exercise (Carter & Greenwood, 2014; Cormier et al., 2022; Ebben, 2002; Fleck & Kontor, 1986). This training format usually involves performing biomechanically similar exercises with a high-load resistance exercise performed first (e.g., squat at 90% of one-repetition maximum [1RM]), followed by a low-load plyometric/ballistic exercise (e.g., squat jump) (Docherty et al., 2004; Fleck & Kontor, 1986). Sequencing exercises in such a format stimulates the post-activation potentiation of performance (Carter & Greenwood, 2014; Docherty et al., 2004; Hodgson et al., 2005; Prieske et al., 2020), subsequently increasing motor unit recruitment and force-production potential of the used musculature (Healy & Comyns, 2017; Thapa et al., 2020). Furthermore, CT may induce neuromuscular adaptations, such as enhanced stretch-shortening cycle function, motor unit recruitment, firing frequency, intra- and inter-muscular coordination, and morphological changes (e.g., fiber type, pennation angle) (Cormie et al., 2011; Markovic & Mikulic, 2010), thus broadly enhancing athletic performance. Another benefit of CT is it provides a time-efficient combination of traditional resistance and plyometric exercise into a single session, which may assist strength and conditioning coaches in overcoming congested weekly micro-cycles (Lim & Barley, 2016; Weldon et al., 2021).

In the last decade, a considerable number of studies have analyzed the effects of CT on soccer player's athletic performance. However, aggregated literature in the form of systematic reviews with meta-analysis are only available for a limited number of physical abilities such as sprint, jump, and change of direction ability (Thapa et al., 2021). Indeed, a recent survey study by Weldon et al. (2021) on the practices of strength and conditioning coaches in professional soccer found the most common application (52%) of plyometric training was in the form of CT when compared to other formats (e.g., before weights, separate days, after weights). However, it is yet to be determined whether CT may favor other key physical abilities such as aerobic endurance, maximal strength, and RSA. Indeed, some studies suggested a greater improvement in aerobic endurance (Miranda et al., 2021), maximal strength (Brito et al., 2014), and RSA (Spineti et al., 2016) after CT compared to single-mode training (e.g., soccer training), but others reported contrasting findings (Faude et al., 2013; Hammami et al., 2017a; Kobal et al., 2017). Part of the controversy in some studies may be related to insufficient statistical power in their analyses, arising from a reduced sample size. Indeed, most studies involving CT among soccer players recruited reduced sample sizes in the experimental interventions (e.g., n=10) (Faude et al., 2013; Kobal et al., 2017; Spineti et al., 2016). A reduced number of participants precludes generalization of findings to other soccer athlete groups (Abt et al., 2020). As an alternative to experimental studies, meta-analysis allows the aggregation of sample sizes from different studies, providing more robust conclusions (Murad et al., 2016). To the author's knowledge, no study has attempted to aggregate the available literature regarding the effects of CT on soccer player's aerobic endurance, maximal strength, and RSA. Therefore, this systematic review with meta-analysis aims to assess the available body of peer-reviewed articles related to the effects of CT on aerobic endurance, maximal strength, and RSA among soccer players compared to active control groups. The results arising from this systematic review may be useful for practitioners to make evidence-based decisions regarding CT interventions for soccer players in relation to the optimization of aerobic endurance, maximal strength, and RSA.

Methods

This systematic review with meta-analysis was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Page et al., 2021). The lead author conducted preliminary electronic searches in PubMed and Google Scholar databases. Articles published up to February 15th, 2022 were considered. The keywords were selected based on a previous meta-analysis study conducted on CT for similar population (Thapa et al., 2021). The following combination of keywords (Using Boolean logic) was used in the search databases: "complex training" or "contrast training" and "soccer". An example of search strategy used in PubMed was: ((complex training) OR (contrast training)) AND (soccer). For Google Scholar database, the

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author used the advanced search option. An example of search strategy in Google Scholar was: with all of the words (complex training soccer); where my words occur (in the title of the article). The same author retrieved the list of articles and removed duplicates. Thereafter, the search results were analyzed according to the eligibility criteria (Table 1).

Table 1. Selection criteria used in the systematic review with meta-analysis.

Category	Inclusion criteria	Exclusion criteria
Population	Apparently healthy soccer players, with no restrictions on their playing level, sex, or age.	Soccer players with health problems (e.g., injuries, recent surgery).
Intervention	A complex contrast training programme, defined as a combination of heavy load strength exercise followed by low load plyometric/power exercise, set by set.	Exercise interventions not involving complex contrast training or exercise interventions involving descending training, where strength training exercises were conducted first and plyometric/power exercises were conducted at the end or during a different session.
Comparator	Active control group (i.e., players participating in regular soccer training) or specific-active control group (i.e., players participating in regular soccer training combined with traditional strength training).	Absence of active control group or specific-active control group.
Outcome	At least one measure related to lower body strength, repeated sprint ability and endurance before and after the training intervention.	Lack of baseline and/or follow-up data.
Study design	Controlled trials.	Non-controlled trials.

For the inclusion of studies two authors (RKT and PN) independently screened the titles, abstracts, and full-text versions of the retrieved studies. Any potential discrepancies between the same two authors regarding the inclusion and exclusion criteria were resolved through the consensus with a third author (RRC). From selected articles, the reference lists were examined to identify further articles for inclusion in the meta-analysis.

Inclusion and exclusion criteria

A PICOS (participants, intervention, comparators, outcomes, and study design) approach was used to rate studies' eligibility (Liberati et al., 2009). Table 1 shows the inclusion/exclusion criteria adopted in this study, with only peer-reviewed articles in English. Articles only published in English were selected considering a recent scoping review which reported 99% of the articles on plyometric jump training (i.e., secondary exercise of CT) research are in English (Ramirez-Campillo et al., 2018).

Methodological quality of included studies

The Physiotherapy Evidence Database (PEDro) scale (https://pedro.org.au/english/resources/pedro-scale/) was used to assess the methodological quality of the included studies, which were rated from 0 to 10, with higher ratings reflecting better quality (Cashin & McAuley, 2020). The validity and reliability of the PEDro scale has been established in previous studies (de Morton, 2009; Maher et al., 2003; Yamato et al., 2017). Two authors (PN and AW) independently assessed the methodological quality of each study, and any discrepancies between them were resolved via consensus with a third author (RKT).

Data extraction

Data were extracted from each eligible study, for aerobic endurance (i.e., Yo-Yo IRT distance [m]), maximal leg strength (1RM squat [kg]), and RSA (mean time [seconds]). Means, standard deviations [SD], and sample size of dependent variables were extracted at pre- and post-CT time points from the included studies using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). However, when data were displayed in a figure or no numerical data were provided by authors after being contacted, a validated ($r = 0.99$, $p < 0.001$) (Drevon et al., 2017) software (WebPlotDigitizer; https://apps.automeris.io/wpd/) was used to derive numerical data from figures. In addition to study data, sample characteristics (age, playing level), training frequency, duration of intervention, type of training protocol, and measurement procedures used in the study were extracted and recorded. Two authors (RKT and PN) performed data extraction independently, and any discrepancies between them were resolved through consensus with a third author (RRC).

Statistical Analysis

Although meta-analyses can be done with as few as two studies (Valentine et al., 2010), it is recommended within sports-science literature due to commonly containing small sample sizes (Pigott, 2012), that meta-analyses are only conducted when >3 studies are available (García-Hermoso et al., 2019; Moran et al., 2018). The DerSimonian and Laird random-effects model was used to compute the meta-analyses. Between group effect sizes (ES, i.e., Hedge's g) were calculated using pre and post-training mean and standard deviations, and each dependent variable was standardized using post-intervention standard deviation values. The ES values are presented with 95% confidence intervals (95% CIs) and interpreted using the following scale: <0.2 trivial, 0.2 – 0.6 small, >0.6–1.2 moderate, >1.2 – 2.0 large, >2.0–4.0 very large, >4.0 extremely large (Hopkins et al., 2009). The impact of heterogeneity was assessed using the I^2 statistic, with values of <25%, 25–75%, and >75% representing low, moderate, and high levels of heterogeneity, respectively (Higgins & Thompson, 2002). All analyses were carried out using the Comprehensive Meta-Analysis software (version 2, Biostat, Englewood, NJ, USA). Statistical significance was set at $p \leq 0.05$.

Results

The initial search resulted in 494 articles being retrieved and 22 additional articles were extracted through other sources (e.g., reference lists of eligible studies). After the removal of duplicates, systematic reviews, and meta-analyses, 510 articles remained. Additional screening of titles and abstracts resulted in the exclusion of 476 articles and 34 full texts were retained. Further screening based on the inclusion and exclusion criteria resulted in the final inclusion of nine studies in the meta-analysis (Figure 1).

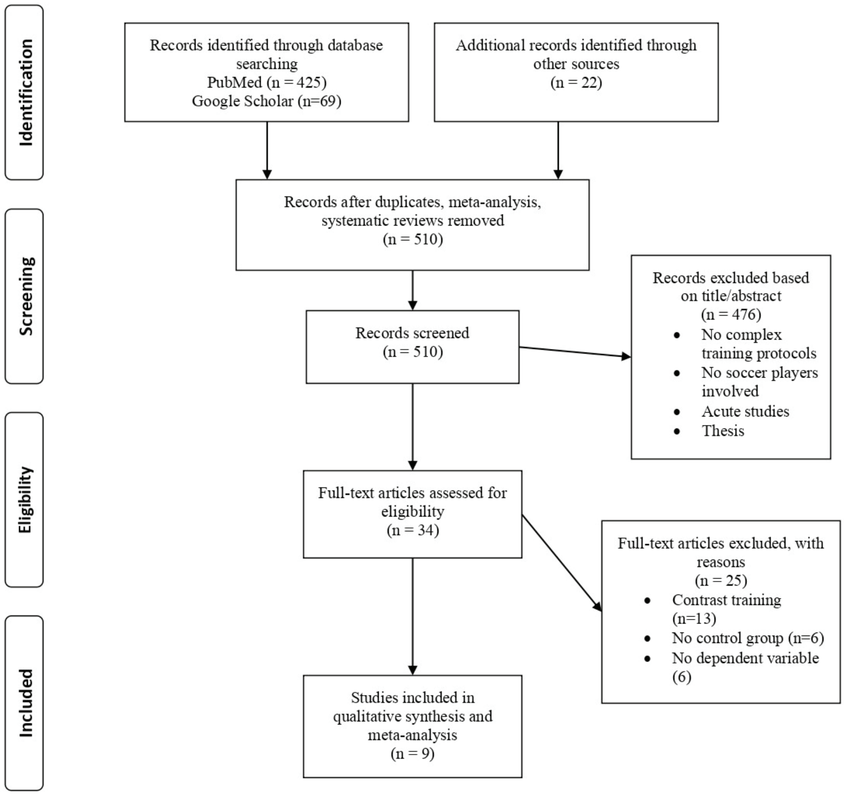

Figure 1. Preferred reporting items for systematic review and meta-analysis (PRISMA) flowchart illustrating the inclusion and exclusion criteria used in the study.

General characteristics of included studies

The study characteristics are presented in Table 2. A total of 211 male subjects were included in this meta-analysis with 112 professional and 99 amateur level players. Among the included studies one study was conducted during the pre-season, seven studies during the in-season, and one study during the off-season period of a competitive schedule (Table 2). The duration of the training programs in the intervention and control groups ranged from four to nine weeks and the frequency of training sessions ranged from two to three per week (Supplementary Table 1). The CT protocol used in each of the included studies are reported in Supplementary Table 1. The testing, measurement and assessment protocols for each of the included dependent variable in the meta-analysis are detailed in Supplementary Table 2.

Table 2. Participant's characteristics from the included studies in the systematic review with meta-analysis.

	Gender	Age (y)	Body mass (kg)	Height (cm)	Playing level	Training period
		Mean				
Brito et a., 2014	Male	20.3	72.0	177.5	College	In-season
Chatzinikolaou et al., 2018	Male	14.2	70.7	178.5	NR	Off-season
Faude et al., 2013	Male	22.5	76.8	179.0	Amateur	In-season
Hammami et al., 2017a	Male	16.0	58.5	173.7	Junior	In-season
Hammami et al., 2017b	Male	16.4	58.7	173.0	Professional	In-season
Hammami et al., 2019	Male	15.8	58.8	174.0	Junior elite	In-season
Kobal et al., 2017	Male	18.9	69.1	176.0	Professional	In-season
Miranda et al., 2021	Male	17.3	66.2	170.0	Professional	Pre-season
Spineti et al., 2016	Male	18.4	70.2	179.9	Professional	In-season

Note: NR – not clearly reported

Methodological quality of included studies

According to the PEDro checklist, the median (i.e., non-parametric) score was 6, with eight studies attaining high quality (6 points), and one study moderate quality (4 – 5 points) (Table 3). The two independent reviewers that performed a methodological appraisal of the included studies achieved a Spearman correlation (i.e., data non-parametric) agreement of 0.75.

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Table 3. Methodological quality of the included studies using the PEDro rating scale.

	1	2	3	4	5	6	7	8	9	10	11	Score*	Study quality
Brito et a., 2014	1	1	-	1	-	-	-	1	1	1	1	6	High
Chatzinikolaou et al., 2018	1	1	-	1	-	-	-	1	1	1	1	6	High
Faude et al., 2013	1	1	-	1	-	-	-	-	1	1	1	5	Moderate
Hammami et al., 2017a	1	1	-	1	-	-	-	1	1	1	1	6	High
Hammami et al., 2017b	1	1	-	1	-	-	-	1	1	1	1	6	High
Hammami et al., 2019	1	1	-	1	-	-	-	1	1	1	1	6	High
Kobal et al., 2017	1	1	-	1	-	-	-	1	1	1	1	6	High
Miranda et al., 2021	1	1	-	1	-	-	-	1	1	1	1	6	High
Spineti et al., 2016	1	1	-	1	-	-	-	1	1	1	1	6	High

A detailed explanation for each PEDro scale item can be accessed at https://www.pedro.org.au/english/downloads/pedro-scale; *From a possible maximal score of 10 (Note: Item 1 is not used to calculate the score).

Meta-analysis results for endurance

Three studies provided data for the Yo-Yo IRT, involving 3 experimental and 3 control groups (pooled n = 55). Results showed a small non-significant effect favouring the CT groups when compared to the control groups (ES = 0.33; 95% CI = -0.19 – 0.85; p = 0.209; Figure 2; I^2 = 0.0%).

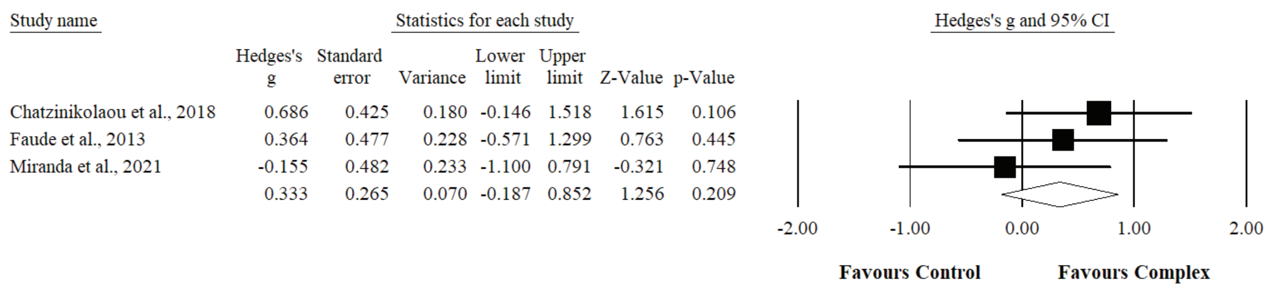

Figure 2. Forest plot for changes in the Yo-Yo test in soccer players after complex contrast training compared to controls. Forest plot values are shown as effect sizes (Hedges' g) with 95% confidence intervals (CI). Black squares represent individual studies and their size represents their relative weights. White rhomboid represents the summary value.

Meta-analysis results for lower body strength performance

Nine studies provided data for squat 1RM, involving 9 experimental and 9 control groups (pooled n = 211; two specific-active control groups). Results showed a large significant effect for the CT groups when compared to the control groups (ES = 1.30; 95% CI = 0.61 – 2.00; p < 0.001; Figure 3; I^2 = 80.6%).

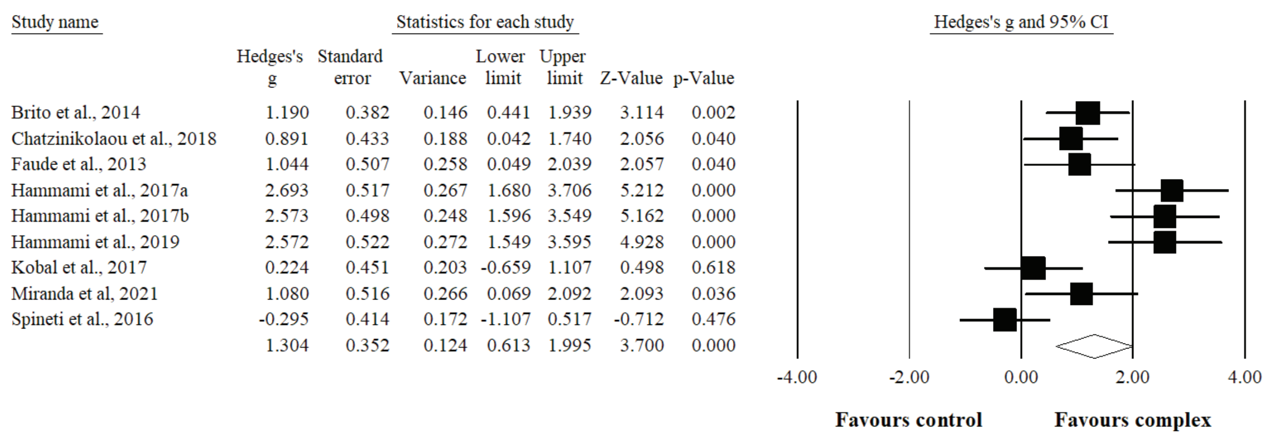

Figure 3. Forest plot for changes in squat one repetition maximum in soccer players after complex contrast training compared to controls. Forest plot values are shown as effect sizes (Hedges' g) with 95% confidence intervals (CI). Black squares represent individual studies and their size represents their relative weights. White rhomboid represents the summary value..

Meta-analysis results for repeated sprint ability performance

Three studies provided data for RSA, involving 3 experimental and 3 control groups (pooled n = 79; one specific-active control group). Results showed a small non-significant effect for the CT groups when compared to the control groups (ES = 0.32; 95% CI = -0.12 – 0.75; p = 0.156; Figure 4; I^2 = 0.0%).

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Spiniti et al., 2016	0.148	0.413	0.170	-0.661	0.956	0.358	0.720
Hammami et al., 2017a	0.438	0.375	0.141	-0.298	1.173	1.166	0.243
Hammami et al., 2017b	0.329	0.369	0.136	-0.394	1.052	0.892	0.373
	0.315	0.222	0.049	-0.120	0.749	1.418	0.156

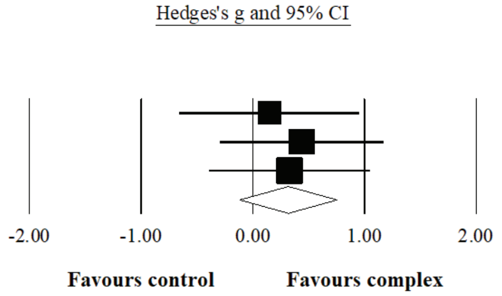

Figure 4. Forest plot for changes in repeated sprint ability in soccer players after complex contrast training compared to controls. Forest plot values are shown as effect sizes (Hedges' g) with 95% confidence intervals (CI). Black squares represent individual studies and their size represents their relative weights. White rhomboid represents the summary value.

Adverse effect of complex contrast training intervention

Among the included studies, no injuries related to CT were reported. In addition, no study reported negative outcomes (i.e., decrement in performance) in any selected variable.

Discussion

This systematic review with meta-analysis aimed to determine the effects of CT on aerobic endurance, maximal strength, and RSA among soccer players. The results of this meta-analysis suggested that CT induced a large significant improvement in lower body strength in male soccer players. However, small but non-significant improvements were reported for aerobic endurance and RSA performance. Among the nine studies that provided data for maximal strength, the potential large beneficial effects were reported across playing levels (i.e., junior and professional), with resistance training exercises at 70 – 90% 1RM, performed 1 – 2 times a week for a total duration of 8 – 9 weeks for lower body maximal strength. Among the three studies that provided data for endurance and RSA, small effects were reported in younger players (i.e., age 14 – 16 years) with minimal strength training experience.

Lower body strength

The large improvement in lower body strength for the CT group may be attributed to specific neuromuscular adaptations such as improved stretch-shortening cycle, increased motor unit recruitment, firing frequency, intra- and inter-muscular coordination, and morphological changes that help with force-generating capacity (e.g., increased tendon stiffness) (Cormie et al., 2011; Healy & Comyns, 2017; Markovic & Mikulic, 2010; Thapa et al., 2021). Indeed, several studies included in this meta-analysis also reported similar benefits in lower body strength with traditional resistance training (i.e., no plyometric or ballistic exercises) (Brito et al., 2014; Chatzinikolaou et al., 2018; Faude et al., 2013; Hammami et al., 2019; Hammami et al., 2017a). However, CT may induce specific adaptations to better optimize the force-velocity profile in soccer players as it incorporates both high-load low-velocity and low-load high-velocity exercises within a session (Cormie et al., 2011). The optimization of the force-velocity curve during training may help with short maximal high-intensity efforts on the field (e.g., changing direction, jumping, sprinting, kicking) due to the recruitment of fast-twitch muscle fibers (Fry et al., 2003; Gołaś et al., 2016; Jiménez-Reyes et al., 2022; Macaluso et al., 2012; Thapa et al., 2021). In addition, CT may also induce hormonal (e.g., increased testosterone) (Ali et al., 2019; Beaven et al., 2011) and structural adaptations (e.g., increased leg muscle volume) (Hammami et al., 2019; Hammami et al., 2017a, 2017b) which may have favored the strength development in soccer players. Therefore, CT can be considered a time-effective mode of training, particularly during the in-season period to improve the lower body strength of soccer players (Lim & Barley, 2016; Weldon et al., 2021).

Endurance and repeated sprint ability

Although the primary adaptation from CT is neuromuscular, therefore may not elicit meaningful changes in aerobic performance (Barnes & Kilding, 2015). However, a recent meta-analysis by Sole et al. (2021) reported small (ES = 0.30) endurance improvements in individual-sport athletes after plyometric-jump training. Similarly, in another meta-analysis Ramirez-Campillo, Andrade, et al. (2021) reported moderate (ES = 0.88) improvement in time-trial performance in endurance runners after plyometric jump training. Indeed, such training may improve anaerobic performance qualities (Assunção et al., 2018) related to endurance performance. Moreover, the neuromuscular adaptations may have improved rate of force development, motor unit recruitment, and increased tendon stiffness (Markovic & Mikulic, 2010), thus positively influencing the running economy of soccer players (Balsalobre-Fernández et al., 2016; Ramirez-Campillo, Andrade, et al., 2021). Furthermore, in this meta-analysis, the sample size for the Yo-Yo IRT was comparatively small (i.e., n = 55) with only three studies included for the final analysis. Out of the three included studies only one group that performed a combination of CT and strength training had a moderate effect (g = 0.69) on Yo-Yo IRT performance (Chatzinikolaou et al., 2018). Possible reasons for such findings may be due to the inclusion of younger male players (i.e., age 14 – 15 years) with no strength training background and additional inclusion of two strength training sessions per week. Therefore, a greater volume in training, lack of previous strength training experience, and no competitive demands during the off-season could have influenced these results. Similarly, three studies reported the effects of CT on RSA, and results indicated that studies incorporating CT for 7 – 8 weeks, elicited small improvements for RSA in young (i.e., ~16 years) junior and professional male soccer players. Indeed, CT may improve the stretch-shortening cycle function via an improved rate of force development, thus sprinting performance (Thapa et al., 2021). However, RSA also relies on aerobic capacity to improve recovery between bouts of maximal sprinting (Jones et al., 2013). Accordingly, it should be considered that the aerobic system plays a role in recovering anaerobic reserves, restoring body temperature, and decreasing the high concentration of

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blood lactate after high-intensity efforts (Dupont et al., 2010).

The results of this meta-analysis suggests that CT may induce small magnitude improvements in aerobic endurance and RSA when compared with soccer training. However, the non-significant difference between CT groups and control groups may be partially explained by the nature of the controls. In this meta-analysis, the active control groups and specific-active control groups were either involved in regular soccer training (Faude et al., 2013; Hammami et al., 2017a; Miranda et al., 2021) or resistance training combined with soccer training (Kobal et al., 2017; Spineti et al., 2016). Therefore, the soccer training itself may have induced physiological changes underpinning the Yo-Yo IRT and RSA performance (Stølen et al., 2005). Alternatively, the use of resistance training only, combined with regular soccer practice, may have led to improvements in the aforementioned outcomes (Miranda et al., 2021; Silva et al., 2015). Additionally, the reduced number of studies included in the meta-analyses for Yo-Yo IRT and RSA performance may have reduced the statistical power of the analyses, as discussed in the limitation section.

Limitations

Limitations of this meta-analysis are; 1) only three studies specifically assessed endurance and RSA. Moreover, the relatively reduced number of participants in each of the included studies in the meta-analysis might have reduced statistical power, thus producing false negative results. Future large randomized-controlled studies should be conducted to produce more robust conclusions; 2) most studies were conducted during the in-season period, which due to the competitive in-season demands, it can be challenging to measure the effect of CT alone on physical performance. Although controlled-study designs may reduce confounding factors arising from regular soccer-related training and competitive demands, future studies are encouraged to provide evidence for CT interventions conducted in periods other than the in-season, and to monitor the potential interference effects of soccer-training through the use of measures such as RPE (or similar); 3) studies not including female soccer players limits the findings to males only, considering physical and physiological differences between both genders. Additionally, considering the increased participation of females in competitive soccer (e.g. a 50% increase in the number of female soccer players was observed between 2000 to 2006 (FIFA, 2007), future studies are encouraged to include female participants; 4) as some studies did not specify the testing equipment used for measurement protocols or the explanation of exercises were ambiguous [e.g., Brito et al. (2014) did not specify the equipment used for 1RM testing], the replication of these studies across different populations may be difficult, as well as their inclusion in moderator analyses. Future studies are encouraged to provide a comprehensive description of the study protocol (including a protocol register), and to follow international guidelines for quality description (e.g., CONSORT guidelines); and 5) related to the previous limitation, no studies reported the intra-set recovery duration between the high-load resistance and low-load plyometric/ballistic exercise, which is a crucial factor in eliciting post-activation performance enhancements.

Conclusions

The findings suggest that combining regular soccer training sessions with CT improves maximal strength compared to soccer training alone. Strength and conditioning coaches may use CT to induce adaptations similar to traditional strength training (e.g., maximal strength gains), while also targeting the force-velocity spectrum (i.e., through plyometric/ballistic exercises) in soccer players. Furthermore, current literature (seven out of nine studies) advocates the use of CT for soccer players during the in-season period. However, strength and conditioning coaches may also use CT during the pre-season period (i.e., during the maximal strength development phase without adverse effects). Indeed, CT may also be used during the off-season period to attenuate the decline of strength/power performance in soccer players. Furthermore, future research should investigate the effects of CT on endurance, maximal strength, and RSA during periods other than the in-season (e.g., pre-season, off-season), across a more diverse range of age groups in male and (particularly) female soccer players from different physical fitness or competitive levels, considering these variables are potential moderators for the effect of CT (Loturco et al., 2020; Sansonio de Morais et al., 2018). In addition, future research should also focus on different intra-set recovery duration, considering that different recovery periods may affect the post-activation performance enhancement (Boullosa, 2021).

Registration

The protocol for this systematic review with meta-analysis was published in the Open Science platform (OSF) on March 06, 2022, under the registration doi 10.17605/OSF.IO/WH3MK. (internet archive link: https://archive.org/details/osf-registrations-wh3mk-v1).

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Conflict of interest

All authors declare no conflicts of interest relevant to the content of this review.

Author contributions

Rohit K. Thapa and Rodrigo Ramirez-Campillo conceived the idea for the article. Rohit K. Thapa, Pushpendra Narvariya, Anthony Weldon, and Rodrigo Ramirez-Campillo performed the literature search and/or data analysis. Rohit K. Thapa, Pushpendra Narvariya, Anthony Weldon, Kaushik Talukdar, and Rodrigo Ramirez-Campillo drafted and/or critically revised the work. All authors read and approved the final manuscript.

Availability of data and material

All data generated or analyzed during this study will be/are included in the published article as Table(s), Figure(s) and Supplementary Table(s). Any other data requirement can be directed to the corresponding author upon reasonable request.

Supplementary tables are available here: https://mjssm.me/suplementaries/supplementary_Thapa.docx

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